Sustainable Agriculture Research; Vol. 12, No. 1; 2023
ISSN 1927-050X E-ISSN 1927-0518
Published by Canadian Center of Science and Education

# Morphological and Physical Diversity of Mangoes (*Mangifera indica* L.) of Local Varieties Found in Noun and Lekié Localities (Cameroon)

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Received: September 1, 2022 Accepted: October 28, 2022 Online Published: November 26, 2022

doi:10.5539/sar.v12n1p1 URL: https://doi.org/10.5539/sar.v12n1p1

**Abstract**

Cameroon has an amazing variety of local mangoes whose potential is poorly exploited. The aim of this study was to characterise the physical and morphological diversity of mangoes in two agro-ecological regions with high potential for mango production. This experiment was conducted between February and July 2021 using ten local mango varieties. These were 'German', 'Bamoun', 'Lady' and 'American' mangoes found in Noun and 'Papaya', 'Dshang Dshang 1', 'Dshang Dshang 2', 'Kousa Dog', 'Garoua' and 'Ladies' mangoes identified in Lekié. Ten ripe fruits of each variety were harvested on three different trees in the same area. A total of 23 morphological and physical parameters were measured. Multivariate analysis based on PCA showed four groups of varieties in decreasing order of importance: group 2 (Papaya, German and American mangoes), group 4 (Garoua, Dame Lékie, Kousa Dog), group 3 (Dshang Dshang 2, Dame Noun, Dshang Dshang 1) and group 1 (Bamoun). Group 2 varieties had good quality for pulp mass to stone mass ratio (5.58±1), size index (10.6±3.22), sphericity index (0.97±0.35), fruit volume (391.5) and lateral fruit diameter (11.05±0.89). However, varieties in group 1 (12.87±3.08) and group 3 (10.7±2.27) have a high proportion of kernels in the fruit and a high kernel density, respectively. There is a wide diversity among the varieties examined. This provides valuable information of the different stakeholders in the mango value chain, i.e., the industry, nurserymen and consumers.

**Keywords:** local mangoes diversity, Morphometry characters, principal component analysis, Cameroon

## 1. Introduction

Mango (*Mangifera indica* L.) is a fruit of the Anacardiaceae family which is a conserved species in recent classifications (APG II and III). It is the third most exported fruit in the world behind banana and pineapple (FruiTrop, 2018). Mangoes grown in heavily forested areas branch much higher than solitary trees and have an umbrella-like form (Bally, 2006). Mango fruit is classed as a drupe, the shape of the leaves and fruits are functions of the cultivars, and the reproductive organs are constituted by the male and hermaphrodite flowers (Magne, 2004). The pulp is rich in nutrients (fiber, sugars, proteins, provitamin A, minerals, etc.) and has great medicinal properties due to its richness in mangiferin and quercetin (Symar, Morag, Ray, Mohammed & Bashirul, 2021). The endocarp is used in the food and cosmetics industry due to its richness in fatty acids and carbohydrates (Nzikou et al., 2010). Very productive in tropical and subtropical regions, the mango is considered "The king of fruits" (Igbari, Nodza, Adeusi, Ogundipe, 2019; Ahmad, Sajid, Iqrar, 2015; Tharanathan, Yashoda, Prabha, 2006). According to FAO statistics in 2020, Cameroon is not one of the African countries exporting mangoes to European and Asian markets. Its production is still low with 639.74 tons produced in 26 years between 1994 and 2020 (FAO, 2020) behind Central African countries such as Chad (32,821.96 tons) and Congo (30,826 tons). Specifically in Cameroon, approximately 93 improved mango cultivars (which are mono-embryonic varieties whose seeds contain an embryo) were successfully introduced (Tchio and Ducelier, 1997). These varieties, although appreciated for their size, flavour and rapid fruiting in the off-season, are limited by their costly grafting method of propagation, and especially by pests such as fruit flies, stone weevils and fungi that cause immature fruit drop. Effective treatment methods are rare and very expensive.

However, Cameroon has great potential in local mango or "green mango" which are polyembryonic (i.e. several embryos that develop from one kernel). These local varieties are dominated by the “Cameroon improved” or “Number one” or “Coastal mango” (Rey et al., 2004). Farmers find these local varieties particularly tasty, drought-resistant and less susceptible to pests than the improved varieties or “colored mangoes” (Sennehenn et al., 2013). These varieties grow rapidly by direct seeding, and are widespread in peri-urban and rural areas behind huts, on roadsides, in fields and in orchards. The potential of Cameroonian mangoes is poorly expressed, as there is very little data on the exact number of existing varieties and no literature on their characteristics.

The aim of this paper is to promote Cameroonian mango's potential by underlining morphological diversity of some local varieties present in the major production regions. These data could be useful for:

i) conservation of germplasm and their use in breeding programs;

ii) to bring elements of choice to food and cosmetic companies;

iii) identify potential rootstock varieties for vegetative propagation programs;

iv) give elements to the exporters to fulfil the specifications necessary to make discover its different flavours in the international market.

## 2. Material and Methods

### *2.1 Study Area*

This study was carried out in two regions, namely the West and Centre of Cameroon, precisely in the Noun and Lekié Divisions (Figure 1).

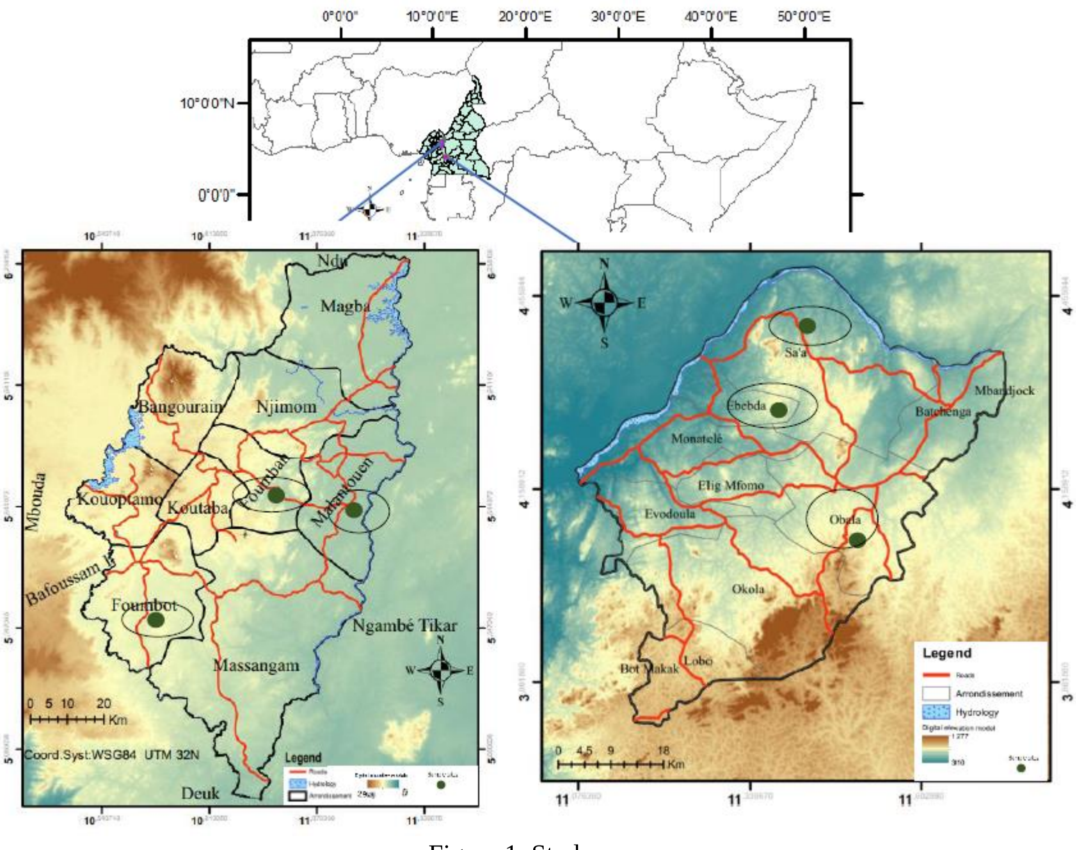


Figure 1. Study area

Lekié Division is located in a bimodal rainforest agro-ecological zone with two distinct seasons with an annual rainfall between 1500 and 2000 mm, with ferralitic or clayed soils (Pompidou, 1999).

The Noun, located in the Western Highlands agro-ecological, benefits from a very wet season (from midMarch to mid November) and annual rainfall varying from 1500 to 2000 mm, with very fertile soils enriched with volcanic materials (Boukar, 2015).

In these two Divisions, the main activities are agriculture and trade, the roads are landlocked, and the markets are periodic. A preliminary survey showed the presence of 4 local varieties in Noun and 6 varieties in Lekié (Mbieji, Mbong, Momo, Kuate, 2021).

*2.2 Collection of Samples*

A field survey was conducted between February and July in both study sites in order to identify and collect the major mango varieties. The ten varieties studied are those identified in the field during the survey period and were chosen for characterization because of their abundance and local appreciation. The plant material used was the ripe fruit of these varieties of local mangoes (Figure 2).

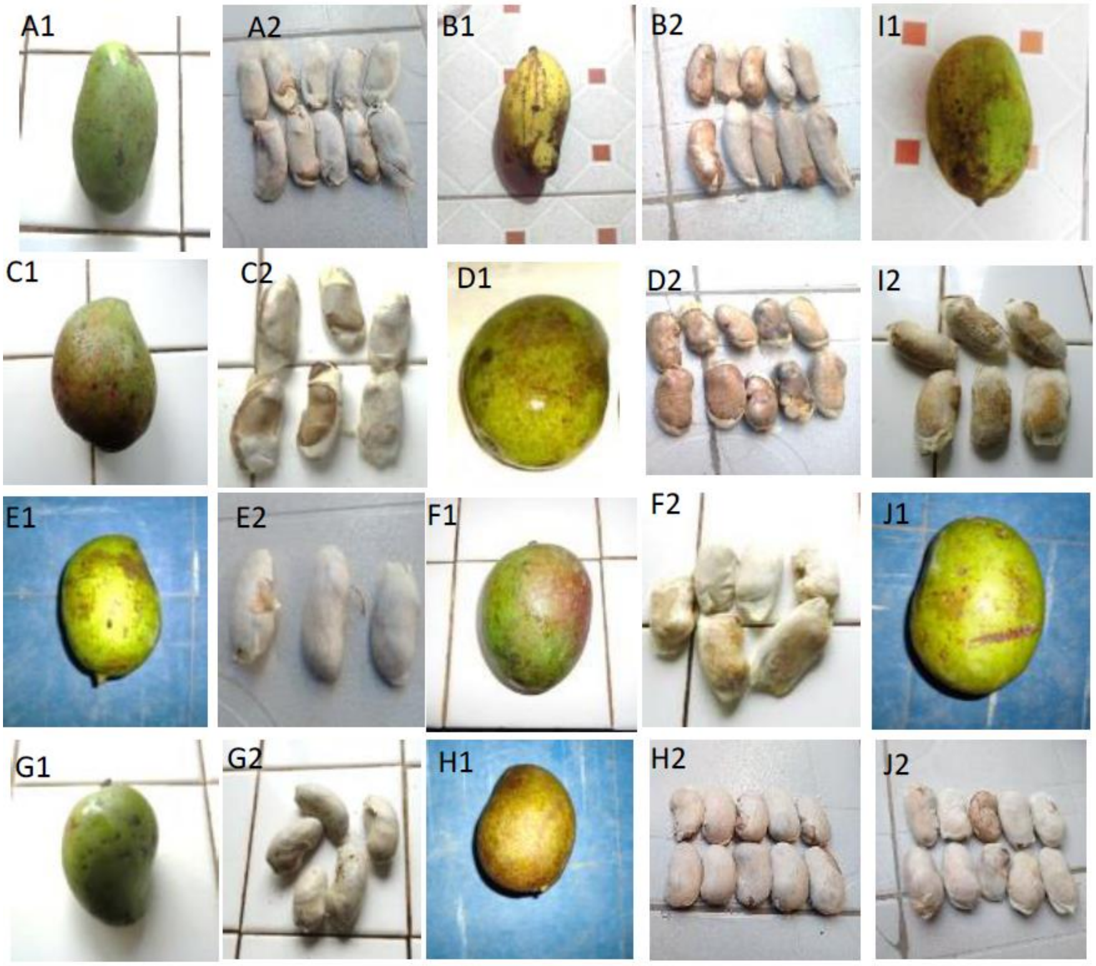


Figure 2. Visualization of some local mangoes and almonds sampled

(A1: 'Dame' Mango Noun and A2: Almond of 'Dame' Mango Noun, B1: 'Dshang Dshang 2' Mango and B2: Almond of 'Dshang Dshang 2' Mango, C1: 'Allemande' Mango and C2: Almond of 'Allemande' Mango, D1: 'Kousa dog' Mango and D2 almond of 'Kousa Dog' Mango, E1:'Dshang Dshang 1' mango and E2: Almond of 'Dshang Dshang1' Mango, F1: 'Americaine' Mango and F2 almond of 'Americaine' Mango, G1: 'Bamoun' Mango and G2 Almond of 'Bamoun' Mango, H1: 'Garoua' Mango and H2: Almond of 'Garoua' Mango, I1:' Dame' Mango of Lékié and I2 Almond of 'Dame' Mango of Lékié, J1 : 'Papaye' Mango and J2: almond of 'Papaye' Mango).

In the Noun Division, two localities were sampled, including Foumbot and Malatouen. Four mango varieties have been collected in these two areas and are known as 'Americaine' mangoes (MANAM), 'Allemande' mangoes (MANALL), 'Bamoun' mangoes (MANBA) and 'Dame' mangoes (MANDN). In Lekié, three localities (Obala, Ebebda and Sa'a) were sampled, and six mango varieties were collected, known as 'Dame' mangoes (MANDL), 'Papaye' mangoes (MANPP), 'Dshang Dshang 1' mangoes (MANDU), 'Dshang Dshang 2' mangoes (MANDD), 'Garoua' mangoes (MANGA) and 'Kousa Dog' mangoes (MANKD) (Table 1).

Table 1. Description of fruit morphological characteristics by variety

| | MANDAN | MANALL | MANAM | MANBA | MANDAL | MANPP | MANGA | MANDU | MANDD | MANKD |
|---|---|---|---|---|---|---|---|---|---|---|
| **Origin of the cultivar** | Open Pollination | | | | | | | | | |
| **propagation** | Seed | | | | | | | | | |
| **Place of collection** | Course | Field | | | Orchard | Field | | Course | | Field |
| **Fruit shape** | Elliptical | Rounded | | | Elliptical | Rounded | | Rounded | Oblong | Rounded |
| **Shape of the fruit apex** | Sharp | | Obtuse | Sharp | | Obtuse | Sharp | Obtuse | Sharp | |
| **Attractiveness of the fruit** | Excellent | Well | Excellent | Medium | Excellent | Excellent | Medium | Well | Medium | Excellent |
| **Color of the skin of the ripe fruit** | Green | Reddish | | Green | Greenish | | Yellowish | Green | Yellow | Greenish |
| **Color of the pulp of the ripe fruit** | Yellow | | | | | | | | | |
| **Texture of the fruit surface** | Smooth | | | | | | | | | |
| **Depth of stalk cavity** | Absent | Shallow | | | Absent | | | | | |
| **Ventral slope of the fruit** | Tilted sharply | High and rounded | Ending with a long curve | High and rounded | Tilted sharply | Ending with a long curve | High and rounded | Ending with a long curve | Tilted sharply | Ending with a long curve |
| **Type of fruit beak** | Noticeable | | | Sharp | Noticeable | | Sharp | Noticeable | | |
| **Type of fruit sinus** | Absent | Shallow | Absent | Deep | Absent | Shallow | | Absent | | Shallow |

### *2.3 Methods*

The investigation consisted of collecting 10 mature and ripe fruits of each mango variety randomly chosen on three different mango trees found in the same area. Each batch of 10 fruits per variety was followed by a marking from F1 to F10 followed by the initial of the variety. A total of 23 pomological parameters were chosen to describe the varieties according to the descriptor published in 2006 by the International Plant Genetic Resources Institute (IPGRI).

#### 2.3.1 Morphometric Parameters

The mass of the mango fruit (MAFRU), pulp (MAPUP), skin (MAPEA), almond (MAAMD) and kernel (MANOY) were measured using an electronic scale (D-Link, MP 10001 type, Max: 1000±0.1g) (Figure 3). The proportion of the pulp (PROPU) was determined by the formula (Equation 1) described by Diakabana, Kobawila, Massengo & Louembe (2013).

$$PROPU = \frac{\mathrm{MAPUP}\times 100}{MAFRU} \quad (1)$$

The volumes of the mango (VOLFRU), the kernel (VOLNO) and the almond (VOLAM) were determined by introducing the whole fruit, the kernel and almond into a 1000 ml graduated cylinder containing water of known volume. The difference between the final volume (after total immersion of the fruit, kernel or almond) and the initial volume (before immersion) corresponded to VOFRU, VOLNO or VOLAM.

The density of almond (DEAMD) was determined by dividing the mass of almond (MAAMD) by the volume of almond (VOLAM) (Passannet, 2018) (Equation 2).

$$\mathrm{DEAMD} = \frac{\mathrm{MAAMD}}{\mathrm{VOLAM}} \ (\mathrm{g/cm^3}) \quad (2)$$

The ratio of the fresh weight of the pulp (MAPUP) and the fresh weight of the kernel (MANOY) allows to evaluate the quantity of pulp or the kernel in the fruit and it is obtained from the formula (Equation 3) (Passanet-2018):

$$\mathrm{MP/MN} = \frac{\mathrm{MAPUP} \times 100}{\mathrm{MANOY}} (\%) \quad (3)$$

The measurement of the dimensions of the fruit and kernel was done using a calliper of accuracy 0.1 cm (Figure 3, A3). For the fruit and kernel, the measurements of longitudinal (DLOFR and DLONO), lateral (DLAFR and DLANO), and thickness (EPAFR and EPANO) were determined.

The morphology of the fruit was given by the sphericity index (INSPH), size index (INDCA) and shape coefficient (COEFF) according to the formula used by Toure et al. (2020); Passannet (2018) and Fagbohoun & Kiki (1999) (Equations 4, 5, 6). The shape coefficient classifies mango varieties into three shape series: COEFF< 0.8 the shape is flattened; COEFF > 1 the shape is elongated and 0.8< COEFF < 1 the shape is round.

$$INDCA = \sqrt[3]{a \times b \times c} \quad (4)$$

$$INSPH = \frac{\sqrt[3]{a \times b \times c}}{a} \quad (5)$$

$$COEFF = \frac{a}{b} \quad (6)$$

Where a is DLOFR, b is DLAFR, c is EPAFR

The measurement of the firmness of the pulp was done by destructive penetrometry using a penetrometer. It consists in determining the degree of ripeness of the fruit and evaluating the tensile and compressive strength of the tip inside the fruit. According to the method used by Méhinagic et al. (2003), five perforations were made at five previously peeled locations on the dorsal part of the fruit. The firmness of the pulp is usually expressed in kilogram-force (kgf) or in newtons (N) (1 kgf = 9.80665 N).


Figure 3. Measurement of the different morphological parameters of the fruit

A1: measurement of the volume; A2: measurement of the mass of the fruit; A3: measurement of the longitudinal diameter of the fruit.

2.3.2 Statistical Analysis

The data collected were subjected to a Principal Component Analysis (PCA) using R software through *Factoshiny* packages. Based on this PCA, some variables that were most correlated with two first axes (PCA1, PCA2) have been selected to characterize diversity among the different local mango varieties. These parameters were also subjected to an ANOVA and the multiple mean's separation using Tukey's test ($P < 5\%$).

## 3. Results and Discussion

### *3.1 Exploration of Varietal Specificities according to Locality of Origin*

The principal component analysis (PCA) explains 54.2% of the discriminatory values of the varieties according to localities. Based on these two first axes, 4 major groups of mango varieties can be defined. Group 1 and 3 are located on the negative side and group 2 on the positive side (Figure 4A & C). These groups are clearly linked to the locality and also to morphological traits collected on different mango varieties. Thus, groups 1 and 3 are characterized by high values of MP_Mn, PROPU, DLANO and VOLNO respectively, while group 2 was characterized by morphological traits that have positive values along PCA1 (e.g., VOFRU, INSPH, INDCA DLONO and MANOY) (Figure 4B). Through this PCA analysis and confidence intervals of scores for each variety, it is evident that there exists a morphological diversity between intra and inter groups.

- Group 1 formed only by MANBA variety is found only in Foumbot quarter Mangoum (FBTMA) and differs from other groups by high values of MP_MN and PROPU.
- Group 2 consisting by individuals of FBNKO (from Foumban) and EBDAO (from Ebebda) which were thought to be composed of three varieties (MANALL, MANAM and MANPP) are morphologically close. However, it was observed that MANALL and MANAM are more similar than MANPP. This grouping is achieved thanks to the variables located at the positive side of PCA1 (Fig 4B), which were most (i.e., VOFRU COEF and INSPH) and medium (i.e., DLNO, POSPC and MAPEA) related to this axis.

- Group 3 was mainly constituted by individuals found in SAMM and SAANO localities and seems to share two morphological characteristics (VOLNO and DLANO) were thus grouped together these three varieties.

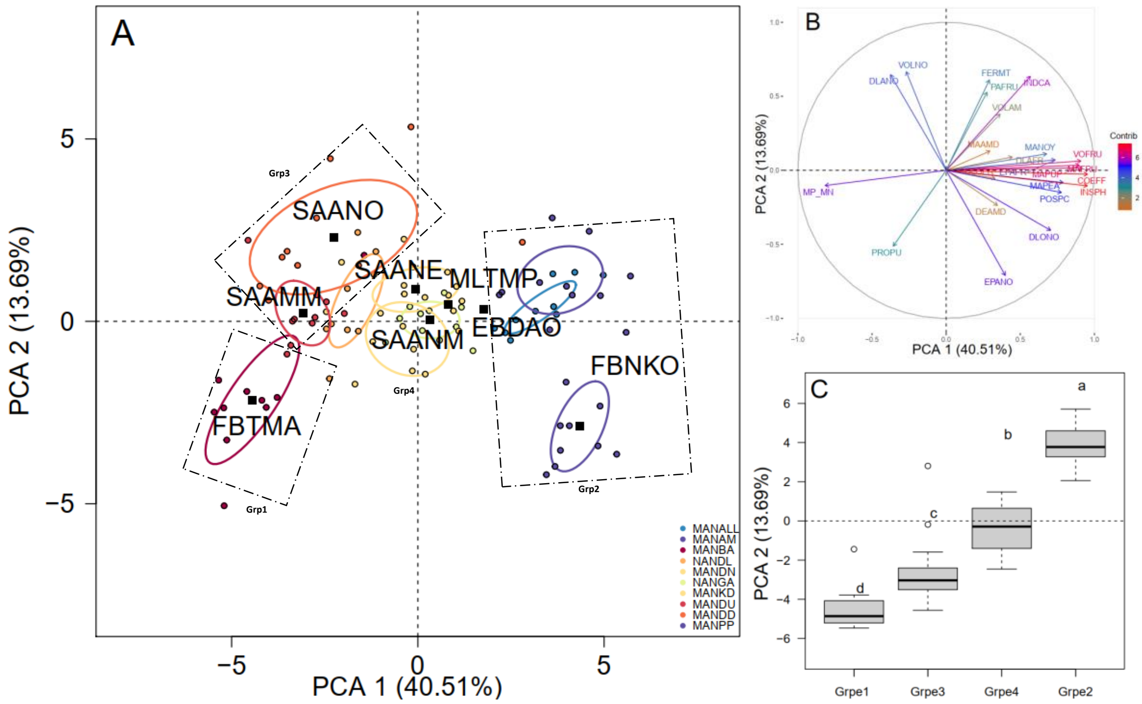


Figure 4. Principal component analysis (PCA)

A) Localities and varieties discrimination according to the first two axes. B) Correlation circle showing the relationship between the types of variables and localities and varieties. C) Boxplot comparing the groups obtained after PCA according to its first dimension. Box with the same letter is not significantly different at 0.05 level

### *3.2 Morphological Characteristics of the Fruits*

#### 3.2.1 Ratio of Pulp Mass to Kernel Mass

The ratio of pulp mass to kernel mass (MP_MN) (Figure 5F), distinguishes varieties with large pulp from those with large kernels. It is higher in group 2 varieties (MP_MN=5.58±1) and lower in group 1 varieties (MP_MN=2.39±0.34). It appears that individuals of group 2 have their pulp mass higher than the other groups, i.e. 5.58±0.34 times their endocarp. These results are different to those found by Passannet (2018), in Chad, who found that maidaguiri mangoes had the highest MP_MN of all other varieties (20.90±8.44). Moreover, these results are in opposition to those found by Lokesh, Singh, & Singh, C (2017) and Tejraj and Anil (2017) with the Mallika variety (7.71 and 4.82) in India. This difference can be justified by the composition of the pericarp of each variety whose biochemical composition (Water, carbohydrate, organic acid, ascorbic acid, proteins and minerals) is controlled by the photosynthetic activity and the capacity of mobilization of nitrogen in the soil by the plant (Frehaut, 2001). Varieties with a large amount of mesocarp are characteristics that may be of interest to some for the manufacture of juice, jam, dried mango and many others. The varieties of group 1 have a larger core because they have a very low ratio of pulp mass to kernel mass (MP_MN=2.39±0.34), these results are in contrast to those of Passannet (2018) with Kassaïmango (55.65±2.16), Lokesh et al. (2017) with Amrapali mango (2.40) and Tejraj and Anil (2017) with Sepiya variety (1.65). These differences could be explained by the genetic composition of the different varieties and the environmental modifications. Indeed, the proportion of the kernel in a fruit is a crucial information because it allows to determine the ratio of the edible part of the fruit.

#### 3.2.2 Size Index and Sphericity Index

The size index (INDCA) (Figure 5D) was used to classify the varieties according to their size, it is higher in the varieties of group 2 (INDCA=10.6±3.22) and lower in the varieties of group 1 (INDCA= 6.22±0.5), group 3 (INDCA=6.91±0.63) and group 4 (INDCA =7.5±0.34) statistically identical. These results are like those found by Passanet (2018), in Chad who found the INDCA ranged from 6.20±0.64 to 10.06±0.52, and very different to those found by Diakabana et al. (2013) in Congo with Boko mango (86.2±10.09). Indeed, the size index was correlated with the volume of the fruit, fresh weight and dimensions of the mango. The difference in the results obtained depends on several factors, notably the capacity of the tree to mobilize the necessary nutrients (Génard & Souty, 1990).

The sphericity index (INSPH) (Figure 5C) was used to assess the shape of a fruit, it was greater in group 2 varieties (INSPH= 0.97±0.35) and lower in the other varieties of the other groups. These results are close with those of Diakabana et al. (2013) (0.88±0.52) and Passannet (2018) (0.88±0.03), and low compared to those found by Touré et al. (2020) in Ivory Coast (1.49±0.06). This can be justified by the genetic composition of the varieties. All the varieties studied have a spherical shape because there INSPH<1.

### 3.2.4 Volume of the Fruit

The fruit volume (VOFRU) (Figure 5K) was larger in group 2 varieties (Vm=391.5±50.6) and smaller in group 1 varieties (VOFRU=174.8±48.9). These results are in disagreement with those found by Passannet (2018), in Chad (607.85±109.1 - 144.73±37.83) and Touré et al. (2020), in north of Ivory Coast (975.33±148.49 - 734.29±70.00). Indeed, there was a correlation between fruit volume and fresh weight of the mango. The differences observed can be justified by the constitution of the mango which contains 85% water and 12% sugar (Lechaudel, 2004). Indeed, the mass of a fruit is a function of the availability of N and C assimilates at the organ level, organ function, the number of storage wells (Triboi & Triboi-B, 2008) and the fruit load (Urban, Bertheuil & Léchaudel, 2002). However, varieties with considerable volume would have important sources, including a very high photosynthetic activity from which important products like carbohydrates and polyholosides are formed (Frehaut, 2001). In addition, tissues such as the xylem and phloem would supply a very important water transit (Grange & Andrews, 1994) which would increase the water mass of the fruit. Other factors such as the intensity of transpiration would have an impact on the size of the fruit. Lescourret, Génard & Fishman (2001) showed in their work that the lower the cuticular water permeability, the higher the fresh mass of the fruit. Moreover, these large size varieties would have a very good functioning of the root system other source, in particular the absorbing hairs which would assimilate the nitrogen in mineral and organic form towards the various wells of which the fruits, although some authors think that the nitrogen is not substantial in the process of growth because it represents 0.1% of the fresh mass and would not influence the quality and the mass of the fruit (Lechaudel, 2004). Some authors also believe that the difference in weight observed in different mango cultivars would be due to the variety or genetic character specific to each (Lokesh et al., 2017).

### 3.2.5 Specific Weight

The specific weight (POSPC) (Figure 5A) of these different varieties ranged from 0.85±0.02 to 0.99±0.15. These results are almost like those found by Passannet (2018), who found that local mangoes from Chad ('Bangui', 'Kassaï', 'Maïduguri' and 'Mangotine') have a specific weight between 0.99±0.03 and 1.01±0.03. On the other hand, Diakabana et al. (2013) found that in Congo, the local mango called 'Boko' had a specific weight of 1.02±0.04. These different specific weight values are close to that of water and give them buoyancy on water, which can be an effective means of sorting during cleaning to separate ripe from unripe fruit.

### 3.2.6 Lateral Diameter of the Fruit

The lateral fruit diameter (DLAFR) (Figure 5G) was higher in individuals of group 2 (DLAFR =11.05±0.85) and smaller than individuals of group 1 (DLAFR =8.6±1.14). These results are close to those found by Touré et al. (2020) (10.72±0.86) as concern group 2 and those found by Lokesh et al. (2017) (8.42±6.36) concerning group 1. The lateral fruit diameter is positively correlated with the pulp mass. This difference can be justified by the biochemical composition of the pericarp of each variety (water, carbohydrate, organic acid, ascorbic acid, protein and minerals) which is controlled by the photosynthetic activity key phenomenon of yield (Ashraf & Harris, 2013), and also by the capacity of mobilization of nitrogen in the soil by the plant (Frehaut, 2001).

### 3.2.7 Morphological Characteristics of Kernels

The proportion of almond in the fruit (PAFRU) (Figure 5E) was higher in group 1 varieties (12.87±3.08 g) and lower in group 2 varieties (6.03±1.43). These results are close with those of Passannet (2018) with the local mango Mangotine (10.46 ±2.3) which is the variety with the highest proportion of almond in the fruit in Chad. The almond of polyembryonic varieties with a high mass was among other criteria for the choice of the best rootstocks by propagators. Indeed, some authors (Armstrong & Westoby, 1993; Vera, 1997; Bonfil, 1998; K. Olorunmaiye, Fatoba, P. Olorunmaiye, Adeyemi, & OreOluwa, 2019) have found that almond weight and size influence agronomic parameters of the plants such as polyembryony, height and number of leaves. In addition, some studies have proved the presence of certain oils in almonds (Ahmed & Eman, 2007) and some polyphenolic compounds (Riberio & Barbosa, 2008) that can be used in cosmetic companies. In addition, the consumption of almonds would provide the body with biological anti-diarrheal (Sairam & al., 2003), anti-bacterial (Thoshihide, Hadjime, Megumi & Shigeko, 2000) and antioxidant (Ahmed & Eman, 2007) activities, which would prevent cardiovascular diseases and arteriosclerosis (Amian, Yaya, N'dri & Siaka, 2019).

Almond density (DEAMD) (Figure 5B) was higher in group 1 varieties (2.56±1.31) g/cm$^3$ and lower in group 2 (1.20±0.48) g/cm$^3$ and group 4 (1.19±0.08) g/cm$^3$ statistically identical. The density allows to determine the amount of material contained in a unit of volume, it can be an index of selection for the actors of the chain of cosmetic and pharmaceutical industries.

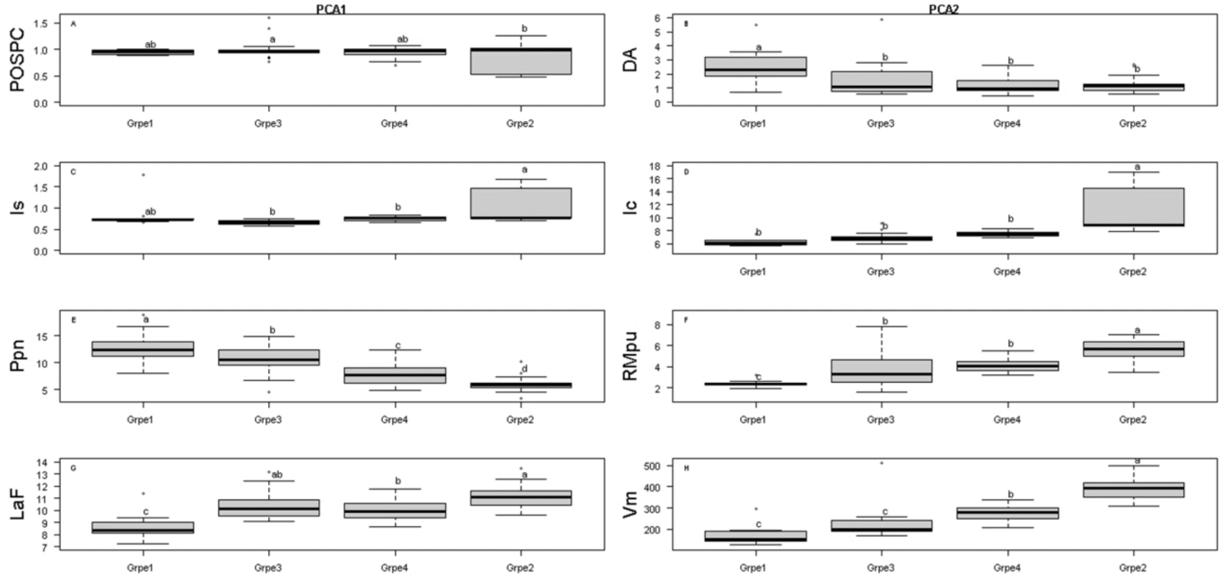


Figure 5. Boxplot illustrating the complementary details of the earlier multivariate analysis based on varietal grouping (PCA)

A) POSPC. B) DA (DEAMD). C) Is (INSPH). D) Ic (INDCA). E) Ppn (PAFRU). F) Rmpu (MP_MN). G) LaF (DLAFR). H) Vm (VOFRU).

## 4. Conclusion

The objective of this study was to describe morphologically and physically the local mango varieties identified in Noun and Lekié. PCA allowed grouped the varieties according to locality and morphological characteristics. Four groups emerged, namely group 1 made up of 'Bamoun' mangoes specific to the locality of Foumbot with good parameters for PAFRU and DEAMD. Group 2 made up of 'Americaine' mangoes, 'Papaye' mangoes, and 'Allemande' mangoes specific to the localities of Foumban, Ebebda and Malamtouem with a specificity for MAFRU, COEFF, INSPH, INDCA, VOFRU and MAPUP. Group 3 consists of Dshang Dshang 2, 'Dame' mangoes of Noun and 'Dshang Dshang 1' specific to Sa'a locality with good POSPC and COEFF parameters, and group 4 consists of 'Garoua' mangoes, 'Dame' mangoes of Lekie and 'Kousa Dog' mangoes. It would be important to collect germplasm from these varieties to confirm the grouping set up by the PCA. Also, to determine the biochemical composition of these different mango varieties as a complement for the cosmetic and pharmaceutical industry, to characterize the agronomic parameters of the varieties with the highest kernel weights in order to confirm their suitability as potential rootstock, and continue the observations in the field by determining their phenology.

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